

Parity violating asymmetry in  
 $\overrightarrow{n} + p \rightarrow d + \gamma$

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for the NPDGamma Collaboration

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# **Measurement of the Parity-Violating Gamma Asymmetry $A_\gamma$ in the Capture of Polarized Cold Neutrons by Para-Hydrogen, $\vec{n} + p \rightarrow d + \gamma$**

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<http://p23.lanl.gov/len/npdg/>

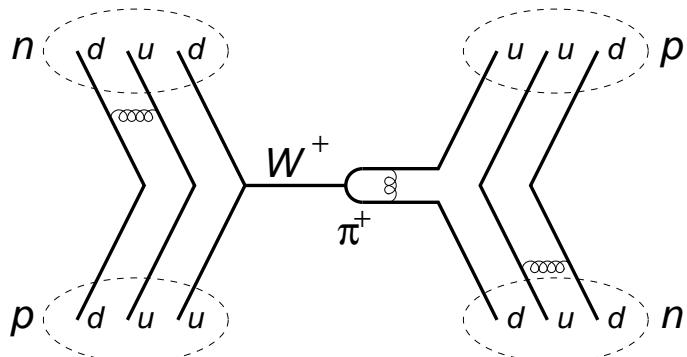
NPDGamma:  $\vec{n} + p \rightarrow d + \gamma$

Measure parity-violating asymmetry  $A_\gamma$  in capture of polarized cold  $n$  by para-H<sub>2</sub>

Expected asymmetry  $\approx 5 \times 10^{-8}$

target experimental error:  $0.5 \times 10^{-8}$

$A_\gamma$  is a clean measurement of  $H_\pi^1$ ,  
the largest weak nucleon-nucleon coupling,  
a fundamental quantity in low-energy QCD  
and weak interaction physics

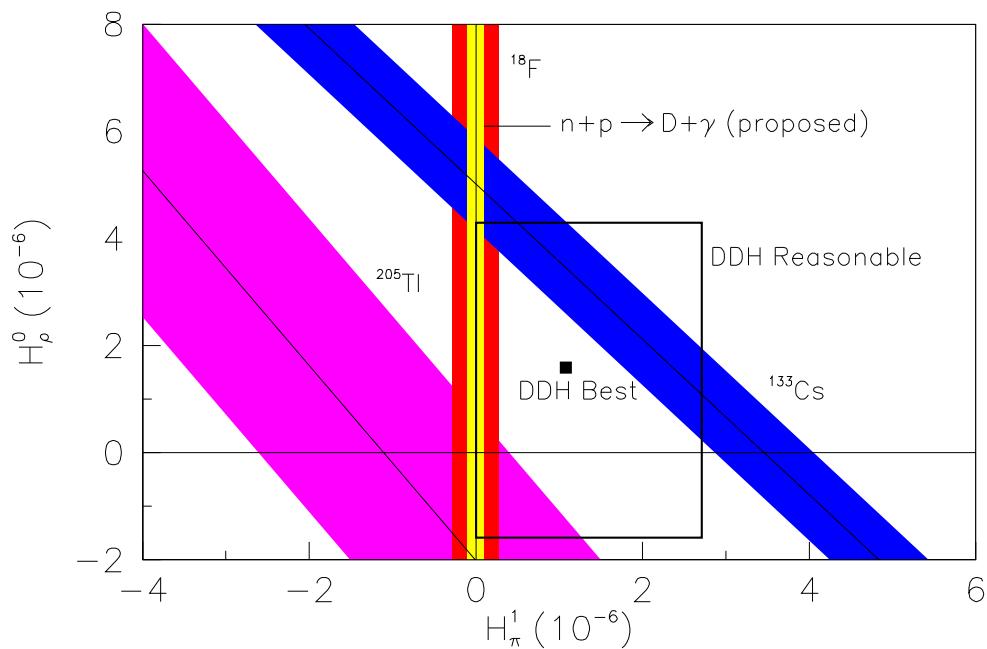


$A_\gamma \approx -0.045 H_\pi^1$ , other weak couplings–

$$H_\rho^0, H_\rho^1, H_\rho^{1'}, H_\rho^2, H_\omega^0, H_\omega^1$$

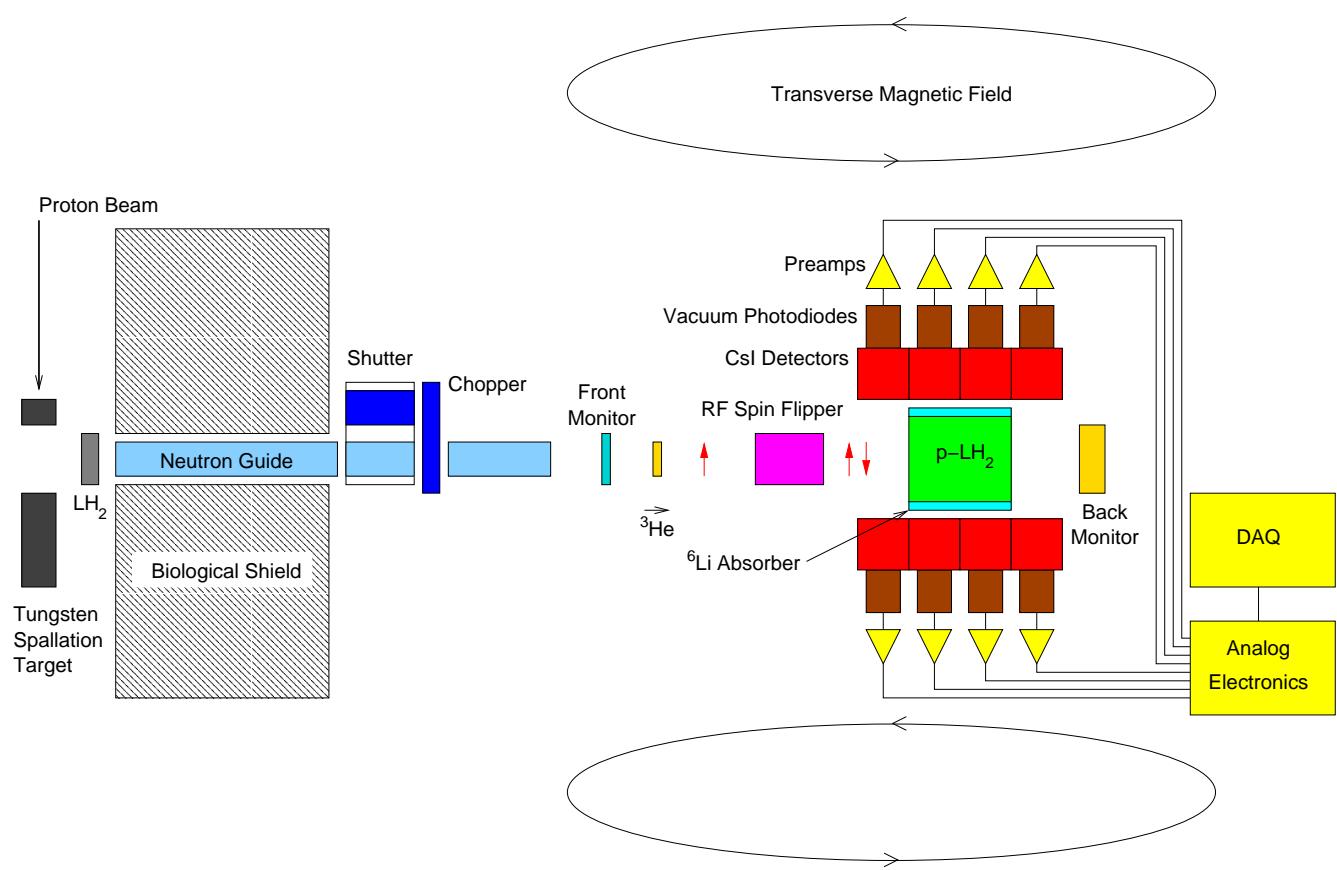
–measured by other observables

## Weak Couplings from $^{18}\text{F}$ , $^{133}\text{Cs}$ , and $^{205}\text{Tl}$



W.S. Wilburn and J.D. Bowman, Phys. Rev. C57  
(1998), 3425.

# NPDGamma Experimental Setup

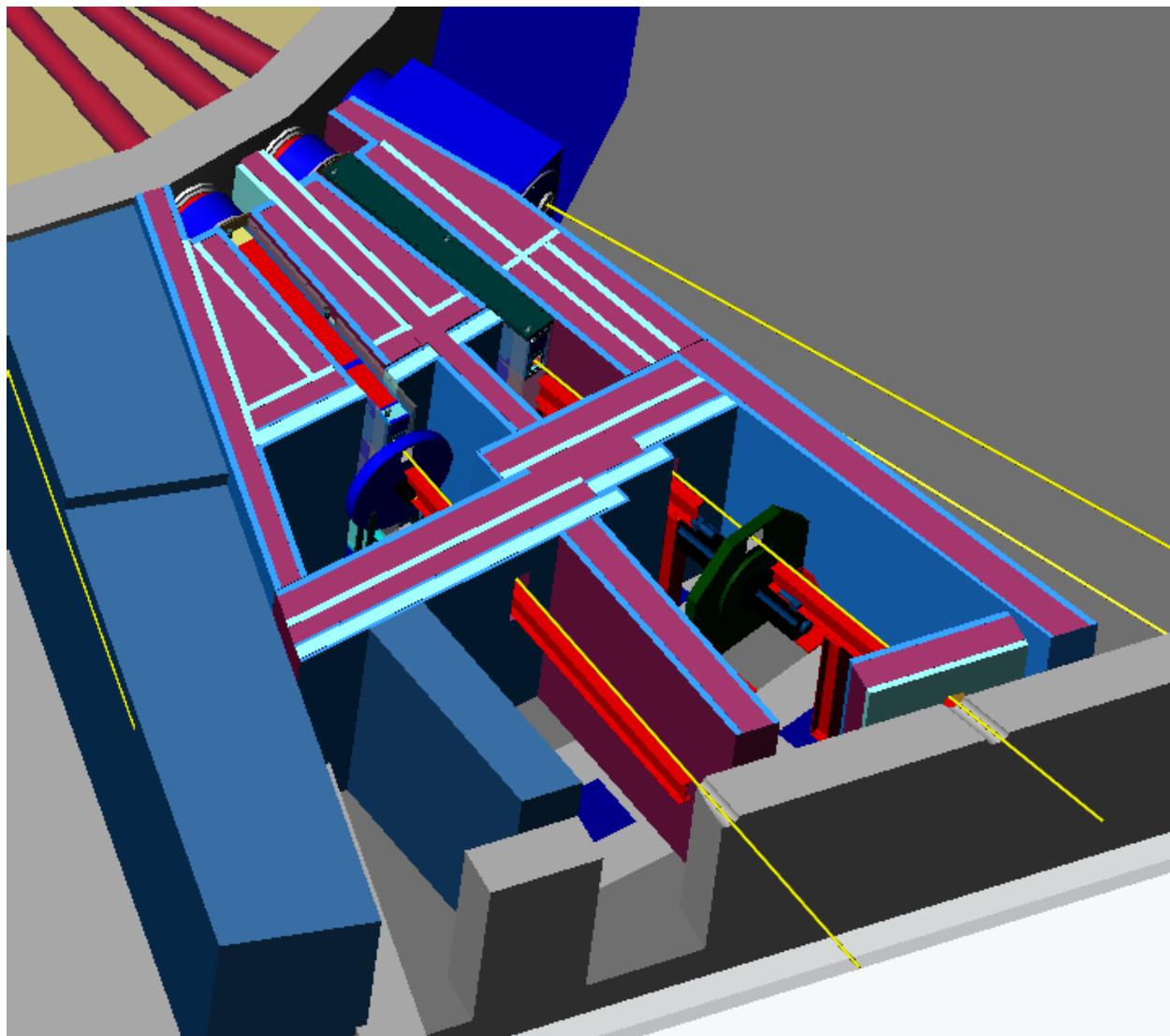


$$d\omega/d\Omega = \frac{1}{4\pi}(1 + A_\gamma \cos \theta_{s,\gamma})$$

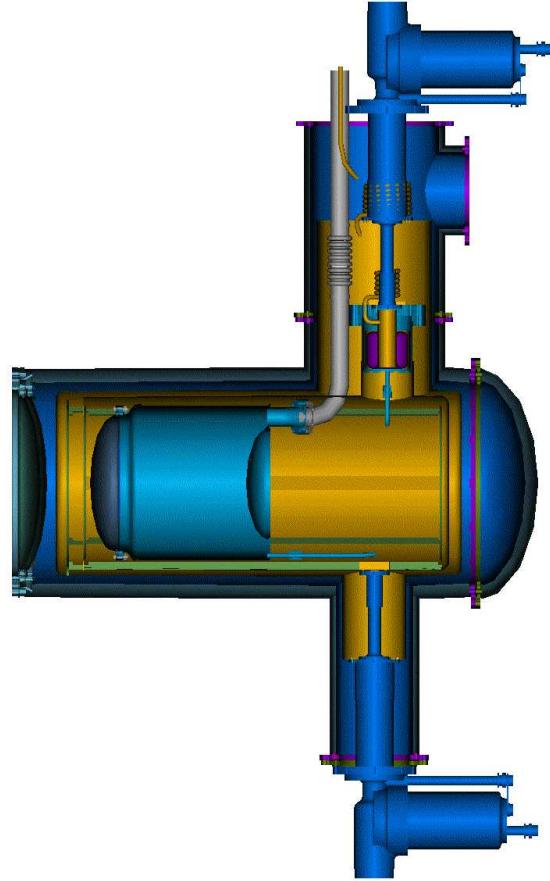
NPDGamma is an approved & funded (\$4.8M) experiment

NPDGamma building FP12 to be ready for:  
commissioning run Fall 2002  
production data taking 2003

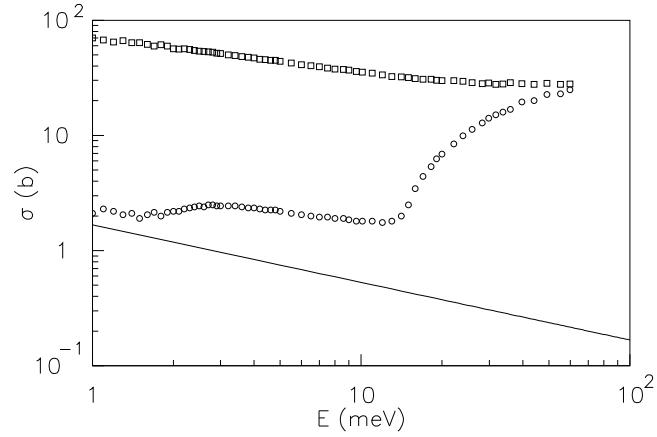
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## Liquid para-hydrogen target



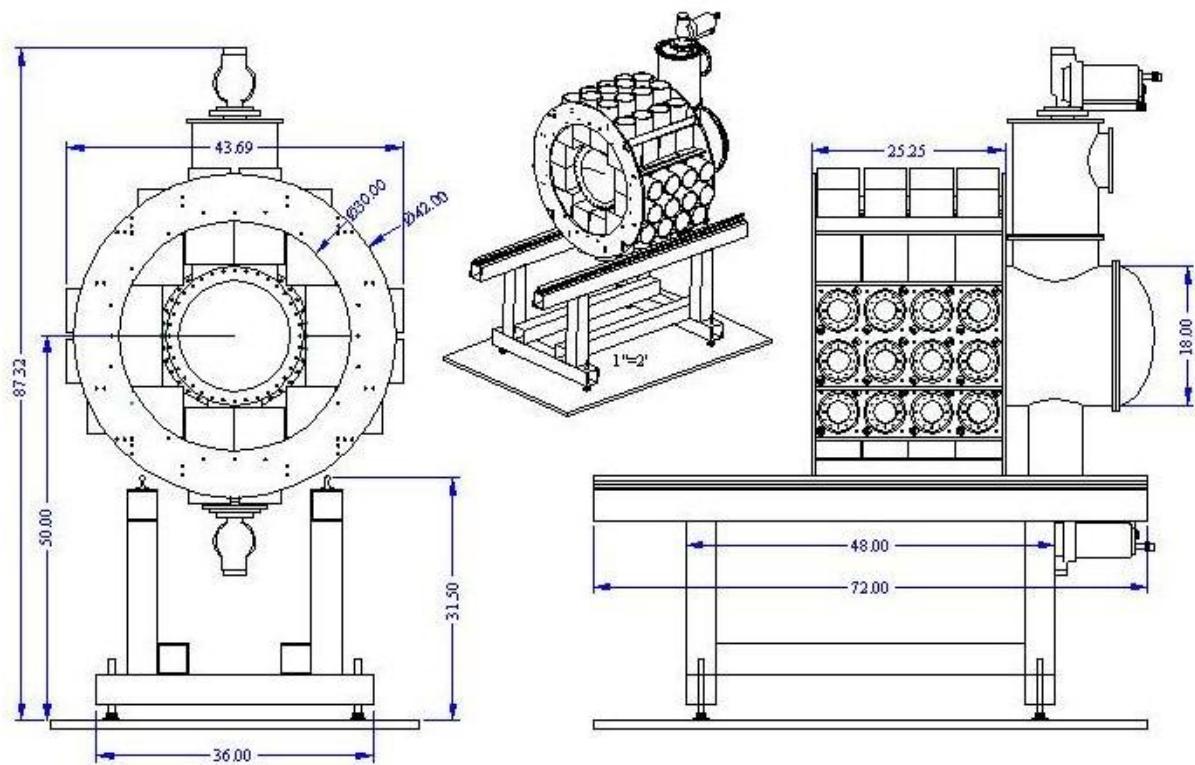
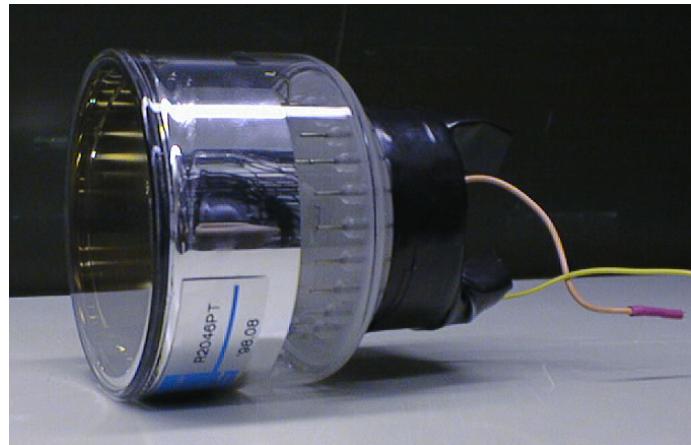
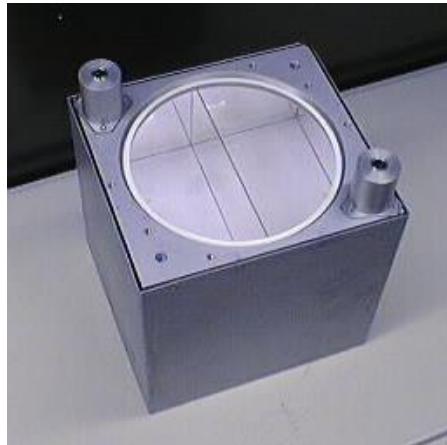
$n$  cross-sections: ortho- ( $\uparrow\uparrow$ ) and para- ( $\downarrow\uparrow$ ) hydrogen  
□ ortho- scattering,  $\circ$  para- scattering, —  $np$  capture



at 17K, ortho- fraction is 0.03%

## CsI(Tl) and Photodiode $\gamma$ Detectors

48 of these detectors will be used in the full experiment



# NPDGamma Fall 2000 Test Run

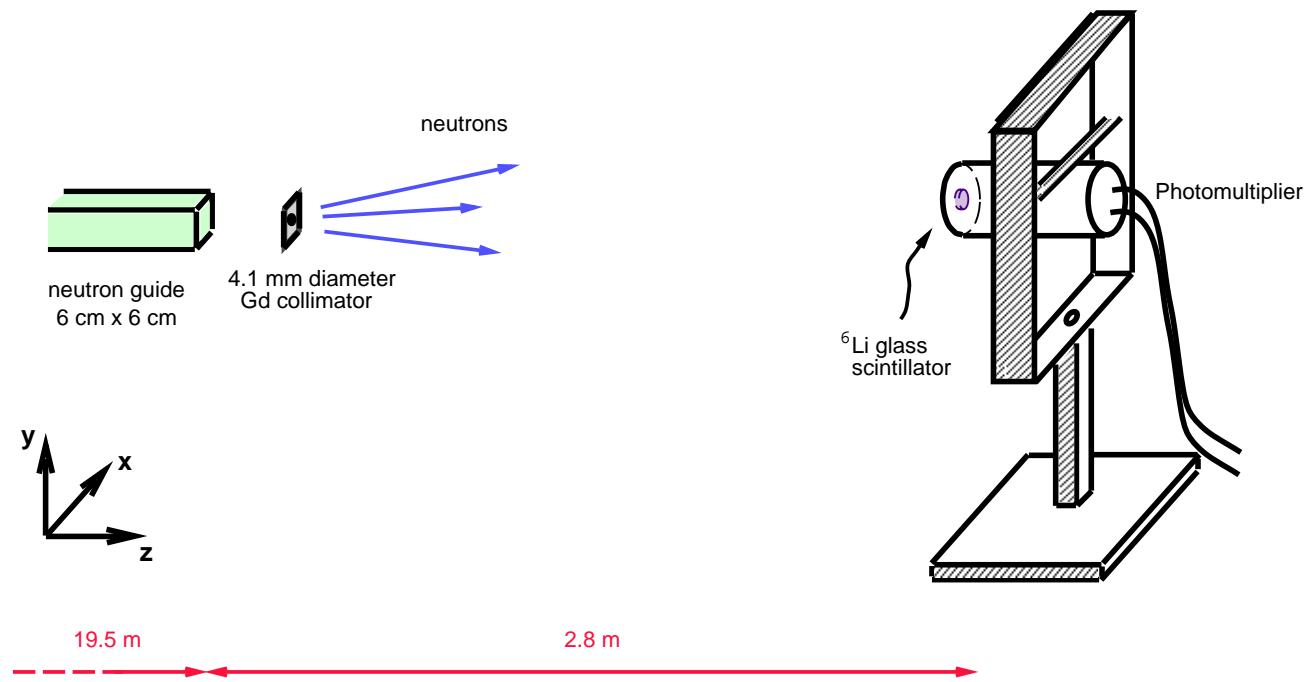
## FP11A

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- measured  $n$  flux to benchmark Monte Carlo
- verified  $n$  intensity fluctuations to be small
- polarized a neutron beam with a  ${}^3\text{He}$  spin filter (thickness 6 atm·cm,  $P \approx 26.5\%$ )
- measured RF spin flipper efficiency ( $> 95\%$ ) vs. energy and position
- used transmission back monitor ( ${}^3\text{He}/\text{H}_2$ ) to observe beam intensity and measure RFSF characteristics
- measured parity-violating neutron capture asymmetries in Cl, La, Cd, to  $\pm 2.5 \times 10^{-6}$  (stat.),  $\pm \text{few} \times 10^{-7}$  (syst.) in eight hours data taking per target, using four CsI(Tl) current mode  $\gamma$  detectors and 3" vacuum photodiodes, and VME-based DAQ system

## Neutron Flux Measurement (FP11A, Fall 2000)

Measured the flux by collimating the beam and counting with a small detector on a movable stage

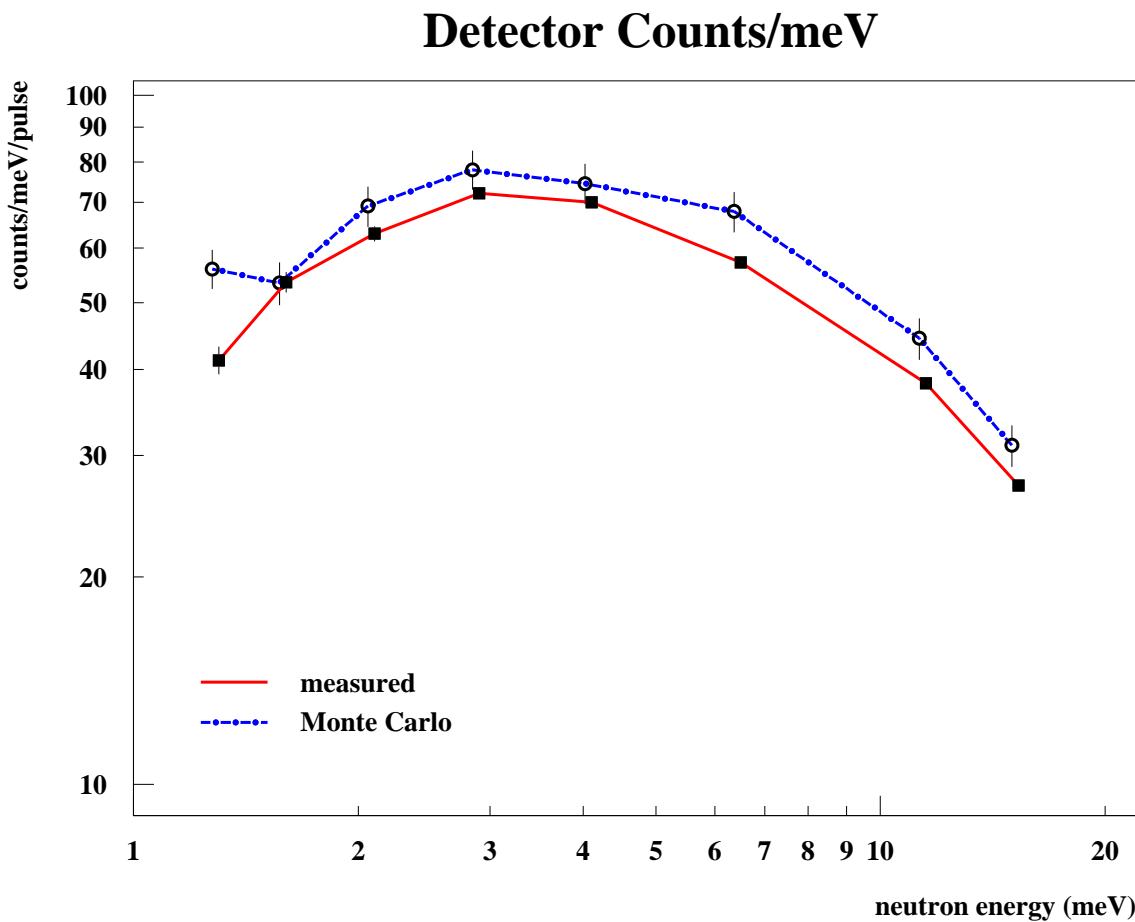


Compare measured flux to predicted flux for a partially coupled  $\text{LH}_2$  moderator, using a Monte Carlo to calculate neutron guide transport and collimation effects for FP11A

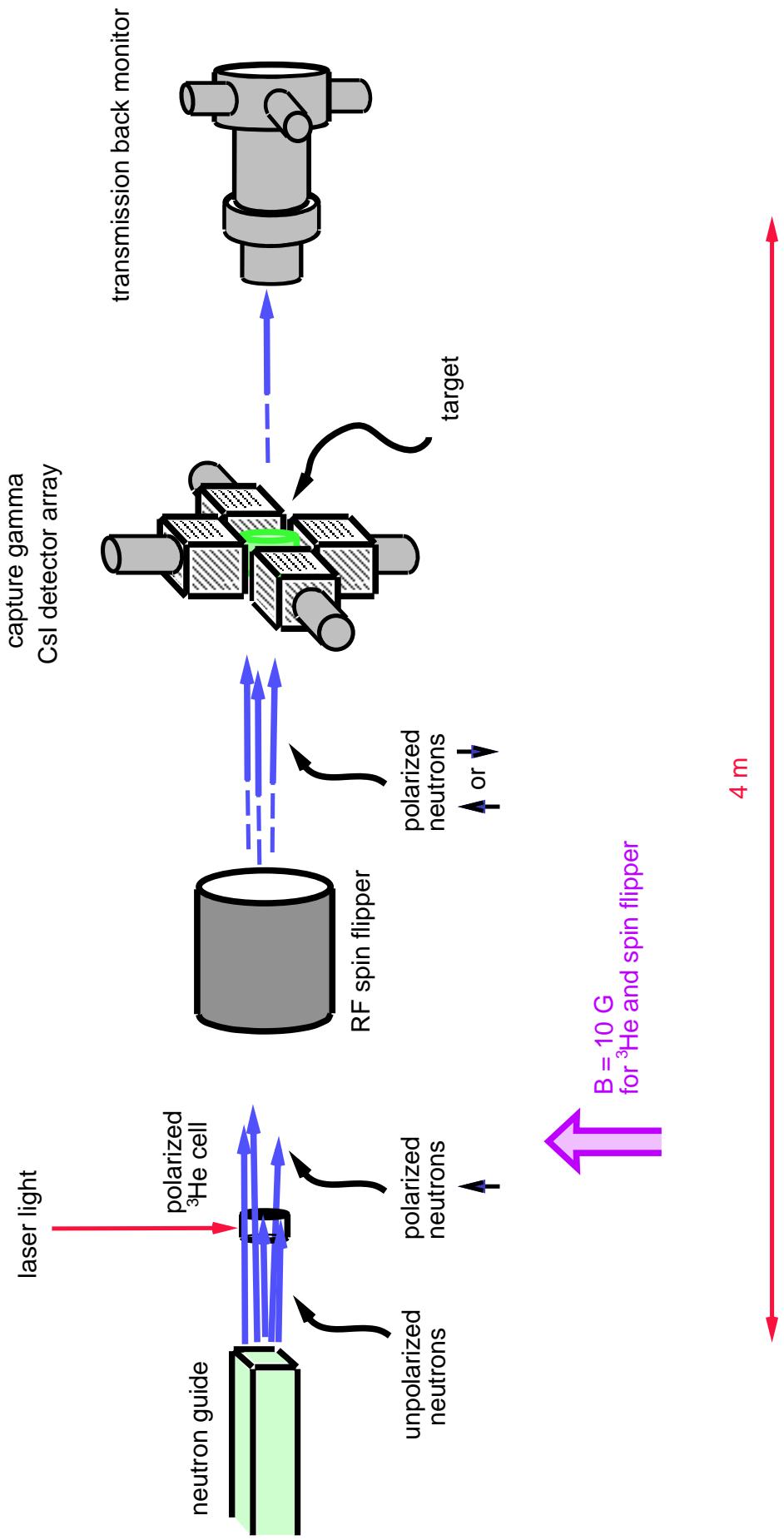
(the moderator brightness prediction is a scaled LAHET calculation by LANSCE)

Excellent agreement (10%)  
with magnitude and E dependence

→ FP12 flux will be as assumed for NPDGamma,  
and have a demonstrated method to measure it



# NPDGamma Fall 2000 Test Run Setup



## $^3\text{He}$ Spin Filter

Optical pumping of Rb vapor →  
polarize  $^3\text{He}$  by spin-exchange collisions . . .

. . . then  $n$  polarized by passing beam through  
the cell. Antiparallel spin neutrons absorbed.

Fall 2000 Test Run:

$^3\text{He}$  polarization of 26.5% →

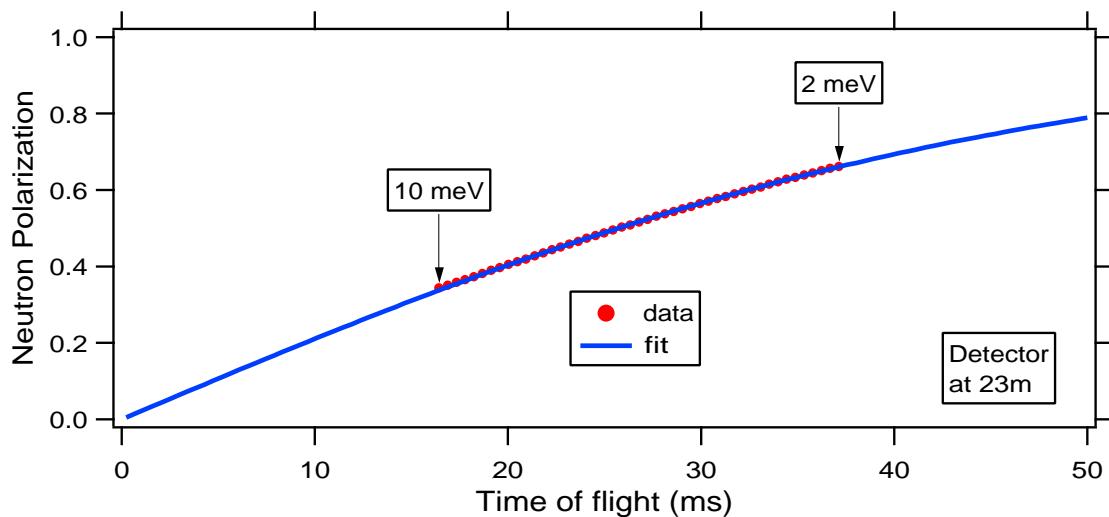
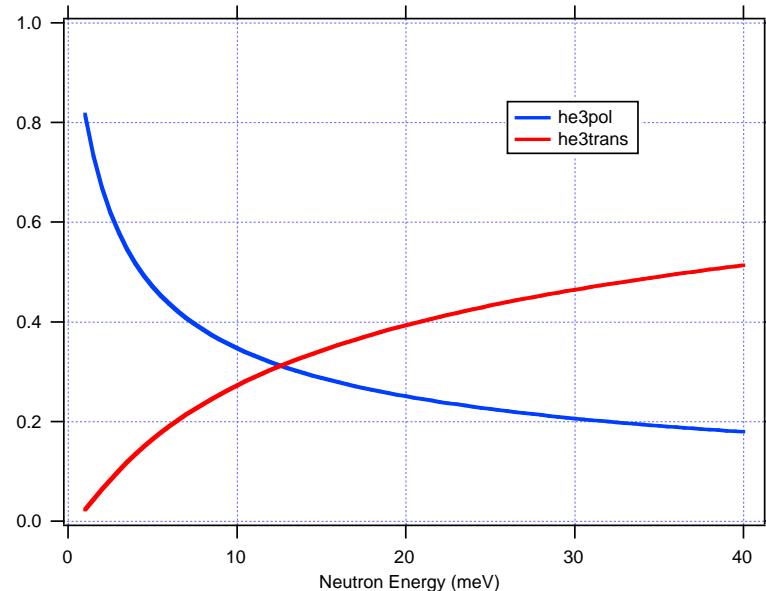
$n$  polarization of 30-70% for 2-10 meV



NIST group has fabricated large single cell:  
12 cm dia.,  $T_1 > 500$  hr → 50%  $^3\text{He}$  pol.

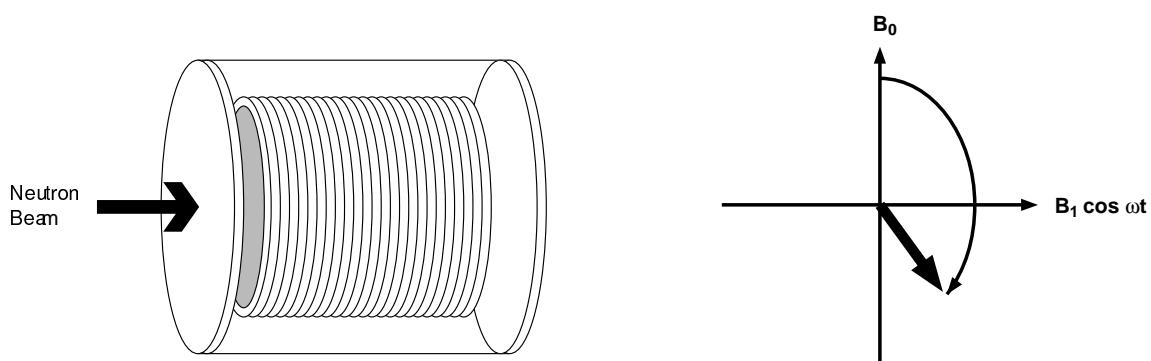
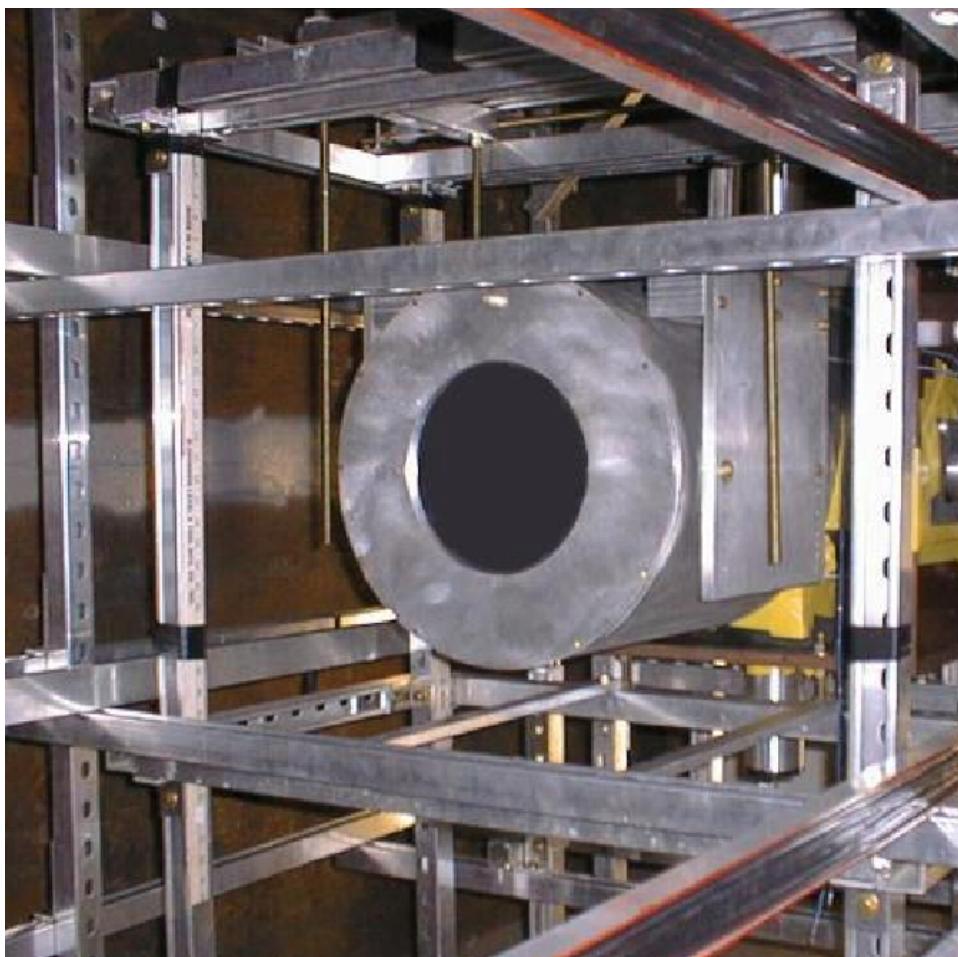
$^3\text{He}$  system  $\rightarrow$  polarized neutron beam

Transmission & polarization depend on neutron energy in a well-understood way



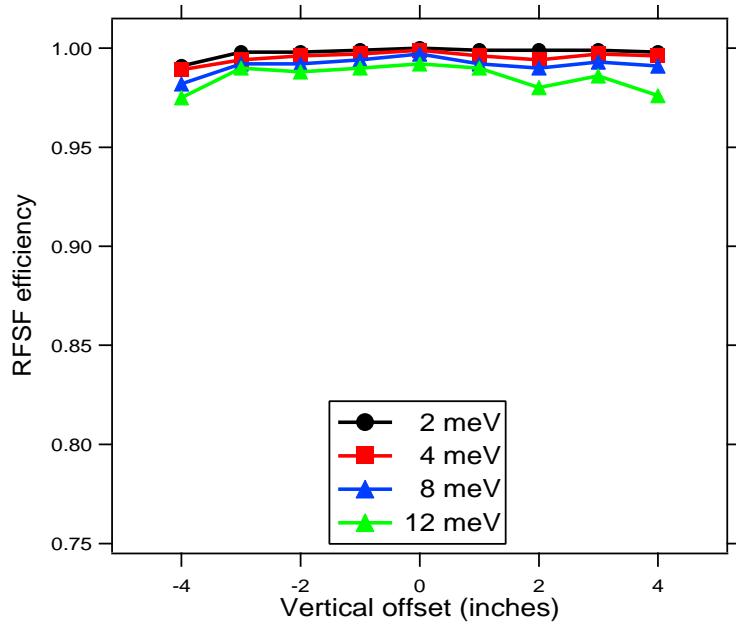
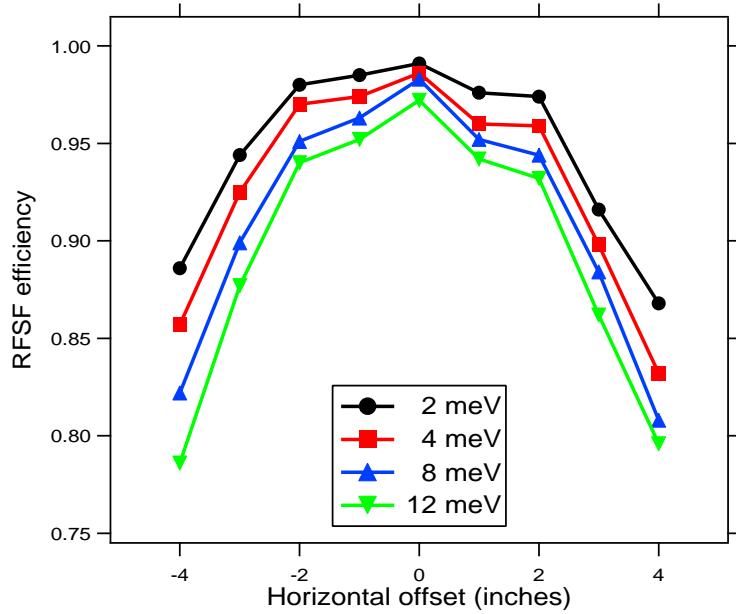
(Data from Fall 2000 Test Run)

## Radio Frequency Spin Flipper



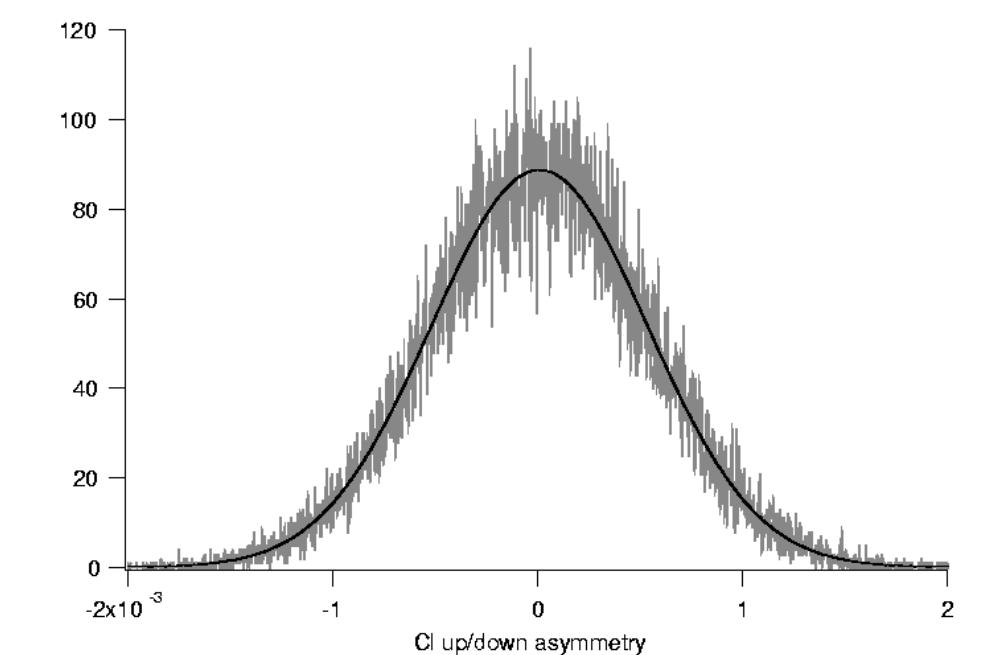
In a DC magnetic field, apply a resonant RF magnetic field to precess the neutron spin by  $\pi$

## Spin flipper efficiency versus position very good (>95% on axis)



# Asymmetry measurements on Cl, La, Cd

up/down → parity violating



**Raw Asymmetries \*10<sup>6</sup>**

	PV $\vec{s}_n \cdot k_\gamma$	PC $\vec{s}_n \cdot (k_\gamma \times k_n)$
<sup>35</sup> Cl	$-7.68 \pm 2.17$	$-2.14 \pm 2.13$
<sup>139</sup> La	$-5.88 \pm 2.35$	$-0.20 \pm 2.26$
<sup>113</sup> Cd	$+1.94 \pm 1.48$	$-1.58 \pm 1.45$

**Parity-conserving (left-right)  $\vec{s}_n \cdot (k_\gamma \times k_n) * 10^6$**

	<sup>35</sup> Cl	<sup>113</sup> Cd	<sup>139</sup> La
Preliminary	$-6.4 \pm 6.4$	$-4.7 \pm 4.6$	$-0.6 \pm 6.6$

**Parity-violating (up-down)  $\vec{s}_n \cdot k_\gamma * 10^6$**

	<sup>35</sup> Cl	<sup>113</sup> Cd	<sup>139</sup> La
BPKLNP	$-27.8 \pm 4.9$	$-1.3 \pm 1.4$	$-17.8 \pm 2.2$
ILL	$-21.2 \pm 1.7$	-	-
Preliminary	$-23.1 \pm 6.5$	$+5.8 \pm 4.4$	$-17.1 \pm 6.8$

## **NPDGamma Status**

- FP12 flight path and experimental cave are under construction.
- Experiment is under construction.  
10% scale apparatus tested Fall 2000.  
All crucial components demonstrated.
- Test runs indicate design is sufficient for target  $A_\gamma$  experimental error,  $0.5 \times 10^{-8}$ .
- Potential systematic errors studied extensively.

## **NPDGamma Schedule**

Fall 2001	FP11a test run
January 2002	Start beamline installation
Fall 2002	FP12 Commissioning Run
Early 2003	Install LH <sub>2</sub> target
July 2003	Begin data taking